

By taking such observations as these in different places it is possible not only to determine the height at which they enter but the velocity with which they pass through the upper regions of the air, even supposing they do not eventually get to the bottom. The lowest velocity determined up to the present time is something like 2 miles per second; the maximum is something like 50 miles a second; but we may say that the average rate of movement is 30 miles a second, which is about 150 times faster than a shell leaving one of our most powerful guns.

J. NORMAN LOCKYER.

(To be continued.)

THE ELECTRIC TRANSMISSION OF POWER.¹ II.

THE next point to consider is the loss of power on the road between the dynamo at the one end and the motor at the other. This problem was perhaps seriously attacked for the first time in the discussion of a paper read by Messrs. Higgs and Brittle at the Institution of Civil Engineers in 1878, and that problem was considered in some detail theoretically and experimentally at the lecture I gave during the meeting of the British Association in Sheffield in the following year. It was then shown that, since the power developed by the generator and motor depended on the product of the current into the electric pressure, while the loss when power was transmitted through a given wire depended on the square of the current and was independent of the electric pressure, the economical transmission of power by electricity on a large scale depended on the use of a very large electric pressure and a small current, just as the economic transmission of much power by water depended on the use of a very large water pressure and a small flow of water. At that time it was not thought possible to construct a small dynamo to develop a very large electric pressure, or potential difference as it is technically called, and therefore it was proposed to join up many dynamos in series at the one end and many lamps or electromotors in series at the other, and to transmit the power by a very small current, which passed through all the dynamos and all the lamps in succession, one after the other.

You have an example to-night of the realization of this principle in the fifteen arc lamps that are all in series outside this Drill Hall, and are worked with a small current of only 6·8 amperes, as indicated in the wall diagram; and a further example in the thirty arc lamps at the Bath Flower Show, which are also all worked in series with the small current passing through them; but it is known now how to produce a large potential difference with a single dynamo, so that a single Thomson-Houston dynamo belonging to Messrs. Laing, Wharton, and Down supplies the current for each of the two circuits.

The electric pressure, or potential difference, between the terminals of any arc lamp is not high, but it is between the main wires near the dynamo as well as between these wires and the ground. How far does this lead to the risk of sparks or unpleasant shocks? That is a point that can be looked at in a variety of ways. First, there is the American view of the matter, which consists in pointing out to people exactly what the danger is, if there be any, and training them to look out for themselves: let ordinary railway trains, say the Americans, run through the streets, and let horses learn to respect the warning bell. Next, there is the semi-paternal English system, which cripples all attempts at street mechanical locomotion, because we are conservative in our use of horses, and horses are conservative in their way of looking at horseless tramcars. Lastly, there is the foreign paternal system, which, carried to its limit, would prohibit the eating of dinners because so ne people have at some time choked themselves, and would render going to bed a penal offence because it is in bed that most people have died.

We laugh a good deal at the rough-and-ready manner adopted on the other side of the Atlantic. The Americans, no doubt, are very ignorant of the difficulties that properly-minded people would meet with, but it is a blissful ignorance where it is folly to be wise. Every English electrician who has travelled in America comes back fully impressed with their enterprise and their happy-go-lucky success. They have twenty-two electric tramways, carrying some 4,000,000 passengers annually, to our four electric tramways at Portrush, Blackpool, Brighton, and Bessbrook. Why, New York city alone, Mr. Rechenzaun tells me, possesses 300 miles of ordinary tramway track, and Philadelphia 430 miles, so there is more tramway line in these two

cities than in the whole of the United Kingdom put together. Now there would be no difficulty in proving, to anyone unfamiliar with railway travelling, that to go at 50 miles an hour round a curve with only a bit of iron between him and eternity would be far too risky to be even contemplated. And yet we do go in express trains, and even 80 miles an hour is beginning to be considered not to put too great a demand on the funds of life insurance companies. The American plan of basing a conclusion on experience rather than on anticipations is not a bad one; and if we follow that plan, then, taking into account that there are 75,000 arc lights alight every night on the Thomson-Houston high-potential circuits throughout the world, and the comparatively small number of people that have suffered in consequence (not a single person, I am assured, outside the companies' staffs) we are compelled to conclude that high potential now is what 30 miles an hour was half a century ago—uncanny rather than dangerous.

But it is possible to use a very large potential difference between the main wires by means of which the electric power is economically conveyed a considerable distance, and transformed into a very small potential difference in the houses where it is utilized. An electric transformer is equivalent to a lever, or wheel and axle, or any other of the so-called mechanical powers. You know that a large weight moving through a small distance can raise a small weight through a large distance; there is no gain in the amount of work, but only a transformation of the way in which the work is done. A large weight moving through a small distance is analogous with a high potential difference and a small current, while a small weight moving through a large distance is analogous with a small potential difference, and a large current, and an electric transformer is for the purpose of effecting the transformation with as little loss as possible, so that what is lost in potential difference may, as far as possible, be all gained in current.

Electrical transformation may be effected by (1) alternate current transformers, (2) motor-dynamos, (3) accumulators, or secondary batteries, (4) direct-current transformers. Of these apparatus, the eldest by far is the alternate-current transformer, as it is merely the development of the classical apparatus invented by Faraday in 1831, and familiar to many of you as the Ruhmkorff, or induction-coil. A combination of a motor and dynamo was suggested by Gramme in 1874. Accumulators are the outcome of Plante's work, while direct-current transformers are quite modern, and not yet out of the experimental stage.

After studying the literature on this subject, it appears, as far as I have been able to judge, that the first definite proposal to use a high potential difference in the street mains, and transform down to a low potential difference in the houses, was made in the lecture given by me at the meeting of the British Association in Sheffield in 1879, on which occasion I explained and showed in action the motor-dynamo principle suggested by Prof. Perry and myself. The apparatus on the platform is not unlike that shown on the former occasion: an Immisch motor working at 500 volts, and with a current of 6·8 amperes, is geared direct to a Victoria Brush dynamo giving five times that current, and we will now use this larger current to produce an electric fire. [Experiment shown.] Messrs. Paris and Scott have combined the motor and dynamo into one machine, which they have kindly lent me, and by means of which we are now transforming about 700 volts and 6·8 amperes into 100 volts and about 40 amperes used to light that group of sunbeam incandescent lamps or work these motors. [Experiment shown.]

Lastly, here is a working illustration of the double transformation proposed by MM. Deprez and Carpentier in 1881, by means of which—while the potential difference between the mains may be 2000 or 10,000 volts, if you like—not merely is the potential difference in the house so low that you could hardly feel anything if you touched the wires, but, in addition, there is the same security against shocks in the dynamo-room. This alternate-current machine is producing about 50 volts, which is transformed up to 2000 volts by means of this transformer. At the other end of the platform, by means of a similar transformer, the 2000 volts is transformed down again to 50 volts, employed to light that cluster of low-voltage incandescent lamps. [Experiment shown.] For the use of this apparatus I am indebted to the kindness of the Anglo-American Brush Company.

In this experiment there is, as a matter of fact, still more transformation than that I have yet mentioned, because, whereas in actual practice the alternate-current dynamo, as well as the small dynamo used to produce the current for magnetizing the electro-magnets in the alternate-current dynamo, would be worked by

¹ Lecture delivered by Prof. Ayrton, F.R.S., at the Drill Hall, Bath, on Friday, September 7, 1888. Continued from p. 511.

a steam, gas, or water engine, I am working them both by electromotors, since a steam-engine or a water-wheel would be an unsuitable occupant of the Drill Hall. Practically, then, a steam-engine on the land belonging to the Midland Railway Company, on the other side of the Lower Bristol Road, is driving a Thomson-Houston dynamo; this is sending a small current working these high-voltage constant-current Immisch motors. The motors being geared with low-voltage dynamos the potential difference is transformed down, the first alternate-current transformer transforms it up again, and the second alternate-current transformer transforms it down again, so that there are in fact three transformations taking place in this experiment on the platform before you. For the benefit of the electricians present, I may mention that the two motors are running in series, and that their speed is kept constant by means of a centrifugal governor which automatically varies the number of the convolutions of the field magnet that are being utilized at any moment. In fact, since the dynamo maintains the current constant that is passing through each motor, the function of the governor may be regarded as that of proportioning the potential difference maintained at the terminals of either motor to the load on the motor at any moment.

A vast district in London, extending from Regent's Park on the north to the Thames on the south, from the Law Courts on the east to Hyde Park on the west, has over 20,000 incandescent lamps scattered over it all worked from the Grosvenor Gallery in Bond Street by means of alternate-current transformers which convert the 2000 volts maintained between the street mains into 100 volts in the houses, and this London Electric Supply Company have arranged for a vast extension of this system to be worked from Deptford.

In America, alternate-current transformers are, due to the remarkable enterprise of Mr. Westinghouse, used to light 120,000 incandescent lamps in sixty-eight towns. In fact the electric lighting of a whole town from a central station begins to excite less astonishment than the electric lighting of a single house did ten years ago.

The efficiency of a well-made alternate-current transformer is very high, being no less than 96·2 per cent. when the transformer is doing its full work, and 89·5 per cent. when it is doing one-quarter of its full work, according to the experiments made by our students. It certainly does seem most remarkable, and it reflects the highest praise on the constructors of electrical machinery, that motive power can be converted into electrical power, electrical power at low pressure into electrical power at high pressure, or electrical power at high pressure into electrical power at low pressure, or, lastly, electrical power into motive power, in each case with an efficiency of not less than 94 per cent.

As a further illustration of the commercial importance of this electric transformation I will show you some experiments on electric welding, one of the latest developments in electrical engineering. To weld a bar of iron one square inch in section requires a gigantic current of some 13,000 amperes. To convey this current even a few yards would be attended with a great waste of power; consequently, while an enormous current is passed through the iron to be welded, only a comparatively small current is transmitted along the circuit from the dynamo to the welding apparatus. Mr. Fish, the representative of Prof. Elihu Thomson, of America, to whom this apparatus is due, will be so kind as to first show us the welding together of two bars of square tool steel, the edge of each bar being $\frac{1}{4}$ of an inch, and the operation is, as you see, entirely completed in some fifteen seconds. For this experiment an alternate current of 20 amperes will be produced by the dynamo at the other side of the Lower Bristol Road, and this current will be converted by the transformer on the platform into one of 9000 amperes, large enough for 12,000 of these incandescent lamps if they were placed in parallel and the current divided among them. He will next try welding some thicker bars, and lastly he proposes welding together two pieces of aluminium which it is extremely difficult, if not impossible, to weld in any other way. The bars, as you see, are in each case pressed together end on, and, in consequence of the electric resistance of the very small gap between the bars being much higher than that of the bars themselves, the current makes the ends of the bars plastic long before it even warms the whole bar, so that I can, as you see, hold the bar at a distance of three or four inches from where the weld has been made without experiencing any marked sense of warmth. The heat is, in fact, applied exactly where we require it, the temperature can be adjusted with the greatest

nicety so as not to burn the steel, and the softening of the bar is effected throughout its entire cross-section. Hence a very good weld indeed can be made by end pressure. We have to thank Mr. Fish, not merely for showing us these most interesting experiments on electric welding, but for supplying the electric power for many of the experiments I have been showing you, and for the electric lighting of the Drill Hall.

To Mr. Snell, the representative of Mr. Immisch, our best thanks are due for his having devoted several days in arranging the two high-voltage, constant-current motors, to drive the dynamos with that constancy of speed which you observe. This ingenious telpher model, to which I shall refer presently, is the handiwork of Mr. Bourne, and considering that it has had to be hastily taken to pieces, and hastily put together again, it is surprising that it works as well as it does. An ordinary watch is a very trustworthy, steady-going machine, but if one had to take it to pieces hastily, and as hastily to put it together again, one might expect it to lose. Indeed, if you or I had to do it, we should not be surprised if it did not go at all, and so was only right twice every twenty-four hours.

For the arrangements of the models and the smaller experiments, as well as for the admirable execution of many of the diagrams, our best thanks are due to Mr. Raine.

Did time allow I should like to describe to you to what perfection the system of economical distribution with accumulators, originally proposed by Sir William Thomson in 1881 and shown in its very simplest form in the wall diagram, has been brought by Mr. King, the engineer to the Electrical Power Storage Company; how the cells when they are fully charged are automatically disconnected from the charging circuit, and electrically connected with the discharging circuit; how the electric pressure on the discharging or house mains is automatically kept constant, so that the brightness of the lamps is unaffected by the number turned on; and how cells that are too energetic have their ardour automatically handicapped, and not allowed to give more current than is being supplied by the less active ones.

During the last few months fierce has been the battle raging among the electricians, the war-cry being "alternate-current transformers *versus* accumulators," while the lookers-on, with that better view of the contest that they are proverbially said to possess, have decided that the battle is a drawn one. Neither system is the better under all circumstances: if the district to be lighted be a very scattered one, use alternate-current transformers by all means; but if the houses to be lighted are clustered together at a distance from the supply of power, then the storing property possessed by accumulators, which enables the supply of electric power to far exceed the capacity of the dynamos and engines in the busiest part of the twenty-four hours, will win the battle for accumulators. Any direct-current system of distribution such as is furnished by accumulators has also the very great advantage that it lends itself to the use of the very efficient electromotors which I have been using this evening. Alternate-current motors do exist, but they are still in the experimental stage, and are not yet articles of commerce.

Secondary batteries have caused much heart-burning, for their users, from the apparent fickleness of their complex chemical action, yet but imperfectly understood. But we have at length been taught what is good and what is bad treatment for them; and after years of brave persevering application on the part of the Electrical Power Storage Company, that forlorn hope the secondary battery has become one of the most useful tools of the electrical engineers; and secondary cells, some of which, thanks to the kindness of that Company, I am using here to-night to supply power for lamps and motors, may now be trusted to have a vigorous long life. That Company, I learn, undertake henceforth to keep their cells in order, when used for central station work, for 12½ per cent. per annum, and I understand that they have such confidence in them that they anticipate making no little money by incurring this insurance office responsibility. It is not, then, surprising that the Chelsea Supply Company have decided to use secondary batteries on a large scale for the economical distribution of light and power in their district.

Oliver Goldsmith said, more than a hundred years ago, in his "Life of Richard Nash, Esquire": "People of fashion at Bath, . . . when so disposed, attend lectures on the arts and sciences, which are frequently taught in a pretty superficial manner, so as not to tease the understanding, while they afford the imagination some amusement." I want not to be superficial, yet I must not tease your understanding, and so we will not lose ourselves in technical details. If, however, my remarks have led

you to appreciate the vast economical importance of using very large electric pressures, and to grasp that, by substituting 2000 volts for 50 volts, when transmitting a certain amount of electric power, the current can be reduced to the one-fortieth part, and the waste of power, when transmitted along a given length of a given wire to the one-fortieth of the one-fortieth—that is, to the one sixteenth-hundredth part—your imagination will have been kindled as well as amused.

With a loss on the road of only 11 per cent., M. Deprez has, by using 6000 volts, transmitted 52 horse-power over a distance of about 37 miles through a copper wire only one-fifth of an inch in diameter. A piece of the actual conductor he employed I hold in my hand: the copper wire is coated with an insulated material, and then with a leaden tubing, so that the outside may be touched with perfect impunity, in spite of the high potential difference employed. M. Deprez's dynamo and motor were not nearly as efficient as he could make them now, so that his terminal losses were unnecessarily great, and the efficiency of the whole arrangement, wonderful as it was, was not so startling as it would otherwise have been. I have told you that the loss in dynamo and motor has actually been reduced to only $12\frac{1}{2}$ per cent.; so that, if a dynamo and motor of this efficiency had been used by M. Deprez, the total loss in the whole transmission over 37 miles would have been under 25 per cent. Indeed, by using only 1250 volts, Mr. Brown has succeeded in transmitting 50 horse-power supplied by falling water at Kriegstetten to Solothun, in Switzerland, five miles away, with an entire loss in the dynamo, motor, and the five miles of going and returning wire of only 25 per cent.; so that three-quarters of the total power supplied by the water at Kriegstetten was actually delivered to machinery at Solothun, five miles away.

In less than twenty years, then, from Gramme's practical realization of Pacinotti's invention, we have power transmitted over considerable distances by electricity with only a total loss of 25 per cent., whereas the combined loss in an air-pump and air-motor or in a water-pump and water-motor is 40 per cent., irrespective of the additional loss by friction or leakage that occurs *en route*. We cannot help feeling that we are rapidly arriving at a new era, and that it will not merely be for the inauguration of the quick transmission of our bodies by steam, or the quick transmission of our thought by telegraph, but for the economical transmission of power by electricity, that the Victorian age will be remembered.

I showed you a little while ago an electric fire. Was that a mere toy, or had it any commercial importance? To burn coal, to work dynamos, and to use the electric current to light your houses and your streets is clean and commercial; to use the current to warm your rooms clean but wasteful, on account of the inefficiency of the steam-engine. But when the dynamos are turned by water power which would otherwise be wasted, the electric current may be economically used, not merely to give light, but also to give heat. And when the electric transmission of power becomes still more perfect than at present, even to burn coal at the pit's mouth where it is worth a shilling a ton may, in spite of the efficiency of the steam-engine being only one-tenth, be the most economical way of warming distant towns where coal would cost 20s. a ton. Think what that would mean!—no smoke, no dust, a reform effected commercially which the laws of the land on smoke prevention are powerless to bring about, a reform effected without the intervention of the State, and therefore dear to the hearts of Englishmen.

I am aware that this idea of burning coal at the pit's mouth and electrically transmitting its power has quite recently been stated to be commercially impracticable. But is that quite so certain?—for in 1878 it was stated that, although telephones might do very well for America, they certainly would never be introduced into Great Britain, as we had plenty of boys who were willing to act as messengers for a few shillings a week. The phonograph was also declared to be worked by a ventriloquist, and electric lighting on a large scale was proved to be too expensive a luxury to be ever carried out. Putting a Conservative drag on the wheels is a very good precaution to take when going down hill, but it is out of place in the up-hill work of progress.

To-day the electric current is used for countless purposes. Not only is it used to weld, but by putting the electric arc inside a closed crucible, smelting can be effected with a rapidity and ease quite unobtainable with the ordinary method of putting the fire outside the crucible. If one had pointed out a few years ago that it was as depressing scientifically to put a fire outside a crucible when you wanted to warm the inside, as Joey Ladle, the

cellarman, found it depressing mentally “to take in the wine through the pores of the skin, instead of by the convivial channel of the throttle,” who would have believed that in 1888, a 500 horse-power dynamo would be actually employed to produce an electric arc inside a closed crucible in the manufacture of aluminium bronze.

But, of all the many commercial uses to which the electric current may be put, probably, after the electric light, electric traction has most public interest. The English are a commercial people, but they are also a humane people; and when, as in this case, their pockets and their feelings are alike touched, surely they will be Radicals in welcoming electric traction, whatever may be their political sentiments on other burning topics of the day. It is not a nice thing to feel that you are helping to reduce the life of a pair of poor tramway horses to three or four years: it would be a very nice thing to be carried in a tramcar for even a less fare than at present. Now, while it costs 6d. or 7d. to run a car one mile with horses, it only costs 3d. or 4d. to propel it electrically. Indeed, from the very minute details that have recently been published of the four months' expenses of electrically propelling thirty cars at $7\frac{1}{2}$ miles an hour along a 12-miles tramway line in Richmond, Virginia, it would appear that the total cost—inclusive of coal, oil, water, engineers, firemen, electricians, mechanics, dynamo and motor repairers, inspectors, linemen, cleaners, lighting, depreciation on engine, boiler, cars, dynamos, and line-work—has been only 14d. per car per mile. This is indeed a low price; let us hope that it is true. The tramway is, no doubt, particularly favourable for propelling cars on the *parallel* system (that is, the system in which the current produced by the dynamo is the sum of the currents going through all the motors on the cars) without a great waste of power being produced by a very large current having to be sent a very long distance, because the tramway track is very curved, and the dynamo is placed at the centre of the curve, with feeding-wires to convey the current from the dynamo to all parts of the track. But even in the case of a straight tramway line with a dynamo only at one end, it is quite possible to obtain the same high economy in working by employing a *large* potential difference and by sending a small current through all the trains in *series*, instead of running the trains in *parallel*, as is done on the Portrush, Blackpool, Brighton, and Bessbrook tramways.

This *series* system of propelling electric trains was oddly enough entirely ignored in all the discussions that have taken place this year at the Institution of Civil Engineers, and at the Institution of Mechanical Engineers, regarding the relative cost of working tramways by horses, by a moving rope, and by electricity; and yet this *series* system is actually at work in America, as you will see from an instantaneous photograph which I will now project on the screen, of a *series* electric tramway in Denver, Colorado; and a *series* electric tramway 12 miles long, on which forty cars are to be run, is in course of construction in Columbus, Ohio. The first track on which electric trams were run in *series* was the experimental *telpher line*, erected in Glynde in 1883 under the superintendence of the late Prof. Fleeming Jenkin, Prof. Perry, and myself, for the automatic electric transport of goods. A photograph of this actual line is now projected on the screen. The large wall diagram shows symbolically, in the crudest form, our plan of *series* working: the current follows a zigzag path through the contact pieces, and when a train enters any section the contact piece is automatically removed, and the current now passes through the motor on that train, instead of through the contact piece. The *Series Electrical Traction* Syndicate, whom we have to thank for the model *series* tramway on which the two cars are now running, are now developing our idea, but it has received its greater development in the States, where the Americans are employing it, instead of spending time proving, *a priori*, that the automatic contact arrangements could never work. Mental inertia, like mechanical inertia, may be defined in two ways. Inertia is the resistance to motion—that is the English definition: but inertia is also the resistance to stopping—that is the American definition.

In addition to the small waste of power, and consequent diminished cost of constructing the conductors that lead the current into and out of the passing trains, the *series* system has another very marked advantage. Some years ago we pointed out that when an electric train was running down hill, or when it was desired to stop the train, there was no necessity to apply a brake and waste the energy of the moving train in friction, because the electric motor could by turning a handle be con-

verted into a dynamo, and the train could be slowed or stopped by its energy being given up to all the other trains running on the same railway, so that the trains going down hill helped the trains going up hill, the stopping trains helped the starting trains. At that time we suggested detailed methods for carrying out this economical mutual aid arrangement whether the trains were running on the parallel or on the series system. But there is this difference, that, whereas on the parallel system it is only when a train is running fairly fast that it can help other trains, the series system has the advantage that, when a motor is temporarily converted into a dynamo by the reversal of the connections of its stationary magnet, the slowing train can help all the other trains even to the very last rotation of its wheels. Brakes that save the power instead of wasting it are of purely English extraction, but their conception has recently come across the Atlantic with such a strong Yankee accent that it might pass for having been born and bred in the States.

Economy is one feature that gives electric traction the right to claim your attention; safety is another. This model telpher line worked on "the post head contact" system is so arranged that no two trains ever run into one another, for, in addition to each of the three trains being provided with an automatic governor which cuts off electric power from a train when that train is going too fast, the line is divided into five sections connected together electrically in such a way that as long as a train is on any section, A, no power is provided to the section B behind, so that if a train comes into section B, it cannot move on as long as the train in front is on section A. [Three trains shown running on a model telpher line with four automatic locks.] Whenever a train—it may be even a runaway electric locomotive—enters a blocked section, it finds all motive power withdrawn from it quite independently of the action of signalmen, guard, or engine-driver, even if either of the latter two men accompanied the train, which they do not in the case of telpherage: no fog, nor colour-blindness, nor different codes of signals on different lines, nor mistakes arising from the exhausted nervous condition of overworked signalmen, can with our system produce a collision. Human fallibility, in fact, is eliminated. While the ordinary system of blocking means merely giving an order to stop—and whether this is understood or intelligently carried out is only settled by the happening or non-happening of a subsequent collision—our automatic block acts as if the steam were automatically cut off; nay, it does more than this: it acts as if the fires were put out in an ordinary locomotive and all the coal taken away, since it is quite out of the power of the engine-driver to re-start the electric train until the one in front is at a safe distance ahead.

The photograph now seen on the screen shows the general appearance of the Glynde telpher line, which has recently been much extended in length by its owners, the Sussex Portland Cement Company; and a telpher line with automatic blocking on the broad principles I have described is about to be constructed between the East Pool tin-mine in Cornwall and the stamps. There will be four trains running, each consisting of thirty-three skips containing three hundredweight each, so that the load carried by each train will be about five tons.

It may be interesting to mention that the last difficulty in telpherage, which consisted in getting a proper adhesion between the driving-wheels of the locomotive and the wire rope, has now been overcome. The history of telpher locomotives is the history of steam locomotives over again, except that we never tried to fit the electric locomotives with legs, as was proposed in the early days for steam locomotives. It is a tedious discouraging history, but it is so easy to be wise when criticizing the past, so difficult to be wise when prospecting the future. Gripping-wheels of all kinds, even the india-rubber tires used for the last three years, have all been abandoned in favour of simple, slightly loose, cheap iron tires, which wear for a very long time, and give a very perfect grip when the bar supporting the electro-motor is so pivoted, pendulum-wise, to the framework of the locomotive that the weight of the motor no longer makes the locomotive jump in passing the posts, as it did until quite recently.

After several years of experimenting, we have in telpherage, I venture to think, at last a perfectly trustworthy, and at the same time a most economical, method of utilizing distant steam- or water-power to automatically transport our goods, and in time it may even be our people, over hills and valleys, without roads or bridges, and without interfering with the crops or the cattle, or the uses to which the land may be put over which the telpher trains pursue their snake-like way: we have, in fact, the luxury of ballooning, without its dangers.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, September 17.—M. Des Cloizeaux in the chair.—Complement to the theory of overfalls stretching right across the bed of a water-course (weirs, mill-races, and the like), by M. J. Boussinesq. In supplement to the theory worked out in the *Comptes rendus* of July 4, October 10 and 24, 1887, the author here deals with the discharge as influenced by the velocities of the currents at the overfall.—On M. Lévy's recent communication on the subject of Betti's theorem, by M. E. Cesaro. This theorem, which plays an essential part in Betti's "Teoria dell' Elasticità," is practically that of Green, which is capable of such manifold applications, and which M. Lévy has shown to admit of so many interesting corollaries in graphostatics. In the present paper M. Cesaro confines himself to proving that the formula of Laplace, giving the velocity of sound in rectilinear elastic mediums, is itself a consequence of Betti's fruitful theorem.—Compressibility of the gases, by M. E. H. Amagat.—On the chlorides of gallium, and on the value of the elements of the aluminium group, by MM. Nilsson and Otto Pettersson. Here are studied the two different chlorides Ga_2Cl_6 (or GaCl_3) and GaCl_2 , as determined by M. Lecoq de Boisbaudran, the discoverer of gallium. The combinations are also given that are formed with chlorine by the elements of the third group of the natural system, whose chlorides have so far been studied. It is pointed out that aluminium and gallium displace three atoms, indium two, and thallium one of hydrogen of the hydrochloric gas. In this group, with the increase of the atomic weight the elements show an evident tendency to form several combinations with chlorine.—On ferrous chloride and the chlorides of chromium, by MM. Nilsson and Otto Pettersson. The preparation and properties are described of ferrous chloride, and of the two known chromium chlorides—the trichloride, CrCl_3 , and the bichloride, CrCl_2 .—Papers were communicated by M. René Chevreul on the great sympathetic nervous system of bony fishes; by M. Alexandre Vitzou on the incomplete intercrossing of the nerve-fibres in the optic chiasma of the dog; and by MM. Raphaël Dubois and Léo Vignon on the physiological action of para- and metapheylene-diamine.

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